A Joint Analysis of Gross Primary Production and Evapotranspiration of Australia Using Eddy Covariance, Remote Sensing and Land Surface Modelling Approaches

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Certificate of original authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text. I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature Date 2017-02-15

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Preface

Accurate estimation of gross primary production (GPP) through vegetation photosynthesis and its coupled evapotranspiration (ET) process is critical for the Earth's life support system. This thesis aims to understand the mechanisms underlying the GPP and ET processes and thus to improve the estimation of them across various spatio-temporal scales. The thesis consists of seven chapters with Chapters two to six written as journal articles. Chapters two to five focus on one of different methods such as eddy covariance, remote sensing and land surface modelling. Chapter six integrates eddy covariance observations, remote sensing products and land surface modelling to investigate the deficits existing in current models. These chapters have been published, submitted or in preparation. This thesis is compiled from above chapters with guidance and support from my supervisors and collaborators from other institutes. The details are as the following:

Chapter 2: Shi, H., L. Li, D. Eamus, J. Cleverly, A. Huete, J. Beringer, Q. Yu, E. v. Gorsel, and L. Hutley (2014), Intrinsic climate dependency of ecosystem light and water-use-efficiencies across Australian biomes, *Environmental Research Letters*, *9*(10), 104002.

Chapter 3: Shi, H., L. Li, D. Eamus, A. Huete, J. Cleverly, X. Tian, Q. Yu, S. Wang, L. Montagnani, V. Magliulo, E. Rotenberg, M. Pavelka, and A. Carrara (2017), Assessing the ability of MODIS EVI to estimate terrestrial ecosystem gross primary production of multiple land cover types, *Ecological Indicators*, *72*, 153-164.

Chapter 4: Shi, H., W. Zhuang, L. Li, J. Beringer, J. Cleverly, J. Dong, D. Eamus, Q. Guo, and Q. Yu (2016), Remote estimation of evapotranspiration for Australian seasonally water-limited ecosystems within an evapotranspiration-vegetation index framework, *Remote Sensing Letters*, submitted.

Chapter 5: Shi, H., L. Li, Y.-P. Wang, J. Beringer, J. Cleverly, L. Cheng, D. Eamus, L. He, X. Lu, L. Zhang, and Q. Yu (2016), Identifying and optimizing key above- and below-ground processes for carbon assimilation and evapotranspiration in the CABLE model across Australian vegetation types, *Journal of Geophysical Research*, internal review.

Chapter 6: Shi, H., L. Li, D. Eamus, X. Lu, Y.-P. Wang, J. Cleverly, J. Beringer, and Q. Yu (2016), Benchmarking the CABLE model using remote sensing GPP and ET products across Australia, *Journal of Hydrometeorology*, in prep.

Other coauthored papers include:

1. Bai, J., J. Wang, X. Chen, G. Luo, H. Shi, L. Li, and J. Li (2015), Seasonal and inter-annual variations in carbon fluxes and evapotranspiration over cotton field under drip irrigation with plastic mulch in an arid region of Northwest China, *Journal of Arid Land*, *7*(2), 272-284.
2. L.H. Li, Y.P. Wang, D. Eamus, V.K. Arora, H. Shi, L. Cheng, J. Cleverly, T. Hajima, D.Y. Ji, C. Jones, M. Kawamiya, W.P. Li, J. Tjiputra, A. Wiltshire, T.W. Wu, Q. Yu, and L. Zhang (2015), Benchmarking global land surface models in CMIP5: analysis of ecosystem water- and light-use efficiencies within a Budyko framework, *Journal of Climate*, under review.
3. L.H. Li, Y.P. Wang, J. Beringer, H. Shi, D. Eamus, A. Huete, J. Cleverly (2015), Coherent and positive response of gross primary production to precipitation across Australian arid and semi-arid biomes, *Scientific Reports*, under review.
4. X.L. Yuan, L.H. Li, X. Chen, H. Shi (2015), Effects of Precipitation Intensity on NDVI-Based Grass Change over Northern China During the Period from 1982 to 2011, *Remote Sensing*, vol. 7, no. 8, doi:10.3390/rs70810164

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Abstract

The aim of this thesis is to analyze the patterns of gross primary production (GPP) and evapotranspiration (ET) across Australian biomes in combination of eddy covariance, remote sensing and land surface model (LSM) methods, taking advantage of their respective applicability on different space and time scales. To do this, I (1) used the wavelet method to decompose eddy covariance observed half-hourly GPP and ET into different frequencies from hourly to annual to investigate the coupling of GPP and ET and their interactions with climate and vegetation variability over hourly to annual time-scales, (2) established GPP-EVI relationships across multiple biomes using observed GPP and MODIS EVI and applied them to the global scale, (3) developed an pure remote sensing ET model (TG-SM) in combination of MODIS EVI, LST and microwave soil moisture data, (4) identified and optimized key above- and below-ground processes of GPP and ET in the CABLE model across 10 Australian flux sites, and (5) benchmarked the CABLE model across the whole Australia through integrative use of remote sensing products of GPP and ET predicted by both my own remote sensing models and other available products.

Each chapter provides new insights into the popular approach for estimating GPP or ET, while together they form a strong example in joint analysis of GPP and ET across various spatio-temporal scales.